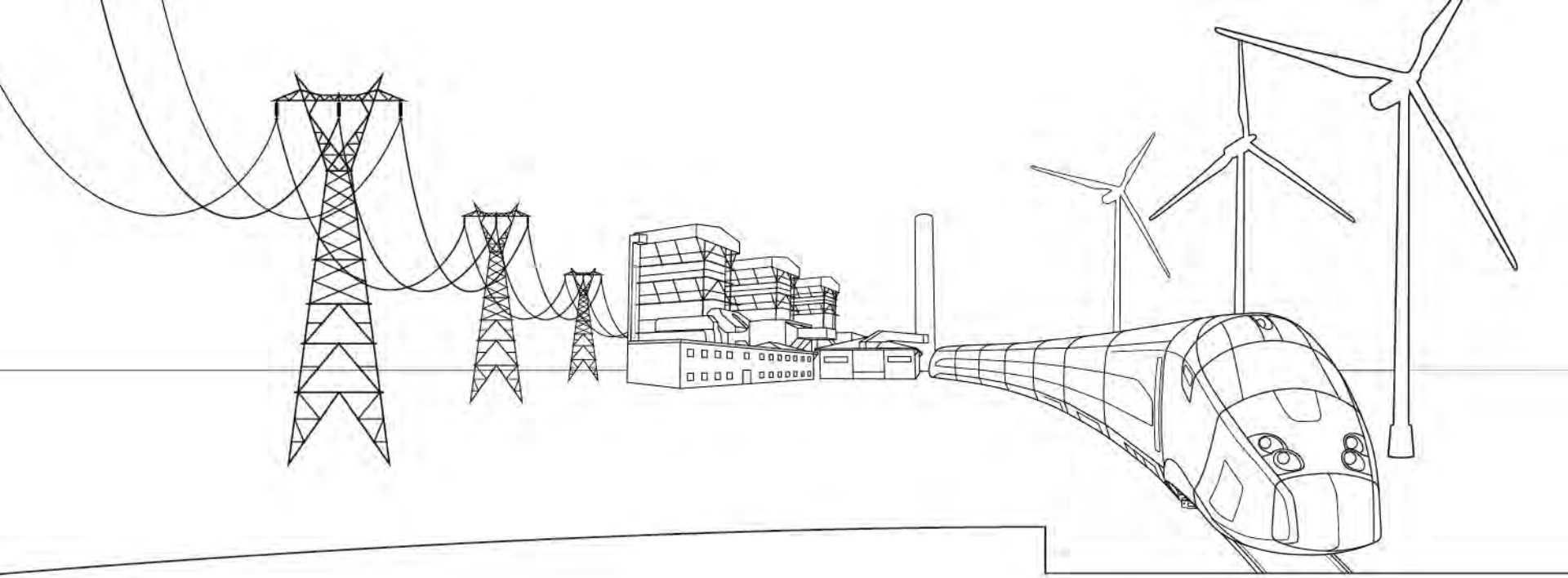
REINHOLD ENVIRONMENTAL Ltd.

2015 Wastewater-Ash Round Table Presentation

September 22, 2015, in Charlotte, NC / Hosted by Duke Energy



Spray Dryer Evaporator for Waste Water Control with Case Studies

Ray Gansley/Phil Rader

Reinhold – Wastewater and Ash Conference

September 22, 2015

ALSTOM
Shaping the future

- **Regulatory Drivers**
- Technology Options
- Direct Evaporation ZLD
- Case Studies
- Summary

Regulatory Drivers

Background

- Congress passed CWA in 1972 to “restore and maintain the chemical, physical, biological integrity of the Nation’s waters.”
- CWA authorizes EPA to establish Effluent Limitation Guidelines (ELG) for sources
- EPA identified steam electric power plants as a category in 1974 at placed limits on thermal and pollutant discharges
- Rules last updated in 1982

ALSTOM

Effluent Limitation Guidelines for Power Plants

- EPA proposes to revise guidelines that may impact 7 waste streams:
  - FGD waste water
  - Fly ash transport water
  - Bottom ash transport water
  - Combustion residual leachate
  - Nonchemical metal cleaning waste
  - Waste water from mercury cleaning systems
  - Gasification waste water
- Final ruling was to be ready by May 2014; delayed, now expected in September 2015
- Compliance timing pending final ruling, state regulators may establish timing requirements for their state

ALSTOM

Effluent Limitation Guidelines for Power Plants

- EPA proposed rules for WFGD WW

Constituent	30 day average	Max 1 day limit
Nitrate/Nitrite	130 ppb	170 ppb
Mercury	119 ppt	242 ppt
Selenium	10 ppb	16 ppb
Arsenic	6 ppb	8 ppb

  - Meet discharge levels prior to comingling with other streams (prevents “dilution solution”)
  - Allows delay in implementation for plants that commit to ZLD solutions

- Coal Combustion Residue (CCR) rules will also provide impetus for water treatment solutions

- Introduction
- Regulatory Drivers
- **Technology Options**
- Direct Evaporation ZLD
- Case Studies
- Summary

WFGD Waste Water

- Portion of scrubbing liquor purged to control steady-state concentrations of chloride and fine inert particles
  - High chloride levels can cause corrosion and performance issues
  - High fine particle levels can impact gypsum purity and cause dewatering problems
- Purge stream constituents:
  - Suspended solids (gypsum, limestone, fly ash)
  - Dissolved solids
    - Ca, Mg, Na salts of Cl, SO_4, SO_3
    - Heavy metals (e.g. Hg, As, Pb)
    - Other elements (e.g. Se, B)

WFGD Waste Water Treatment Methods

- Surface impoundments
  - Gravity separation of suspended solids
  - Commingle with other waste water streams
  - Clarified water discharged; settled solids landfilled
- Chemical precipitation
  - Precipitate heavy metals
  - Coagulation/flocculation followed by thickening/filtration
  - Treated water discharged; precipitated solids landfilled
- Biological treatment
  - Used to treat Se, other metals, and DBA
- Brine concentration
- Constructed wetlands

Waste Water is Discharged into Surface Water

ALSTOM

Methods to Eliminate WFGD Waste Water Discharge

- Evaporation ponds
  - Limited to southwestern US
- Fly ash conditioning/fixation
- Brine concentration/crystallization
- Underground injection
- Direct evaporation

Zero Liquid Discharge to Surface Water

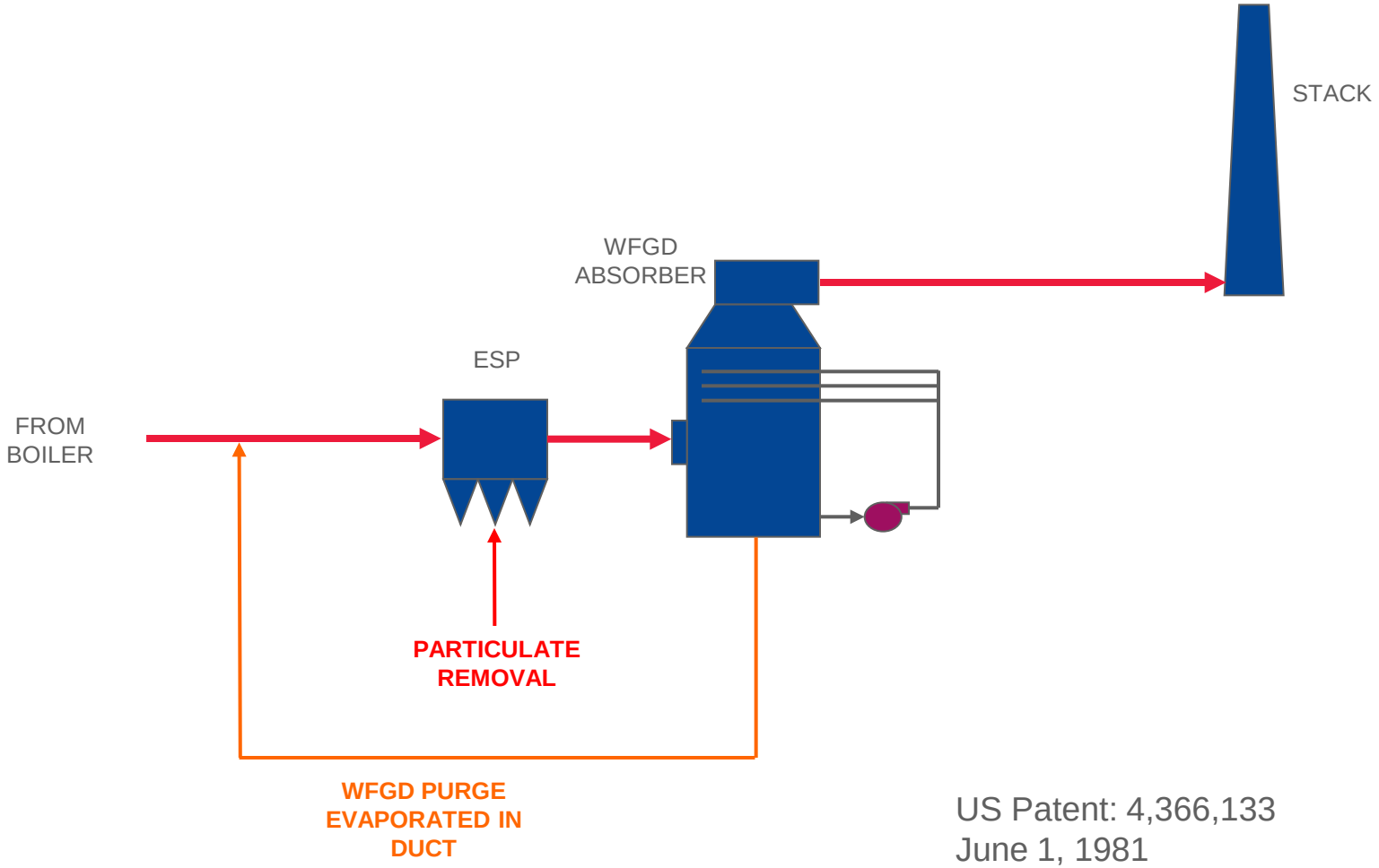
Direct Evaporation Advantages

- True ZLD – no purge stream to permit, monitor, and report
- Wide applicability as retrofit solution
- Simplicity
  - Fewer unit operations than most conventional WWT
  - No secondary solid waste stream
- Proven technology
  - Spray dryers in service in power plants since mid-1970s
  - Duke Cliffside 6 evaporating WFGD waste water since Fall 2012

ALSTOM

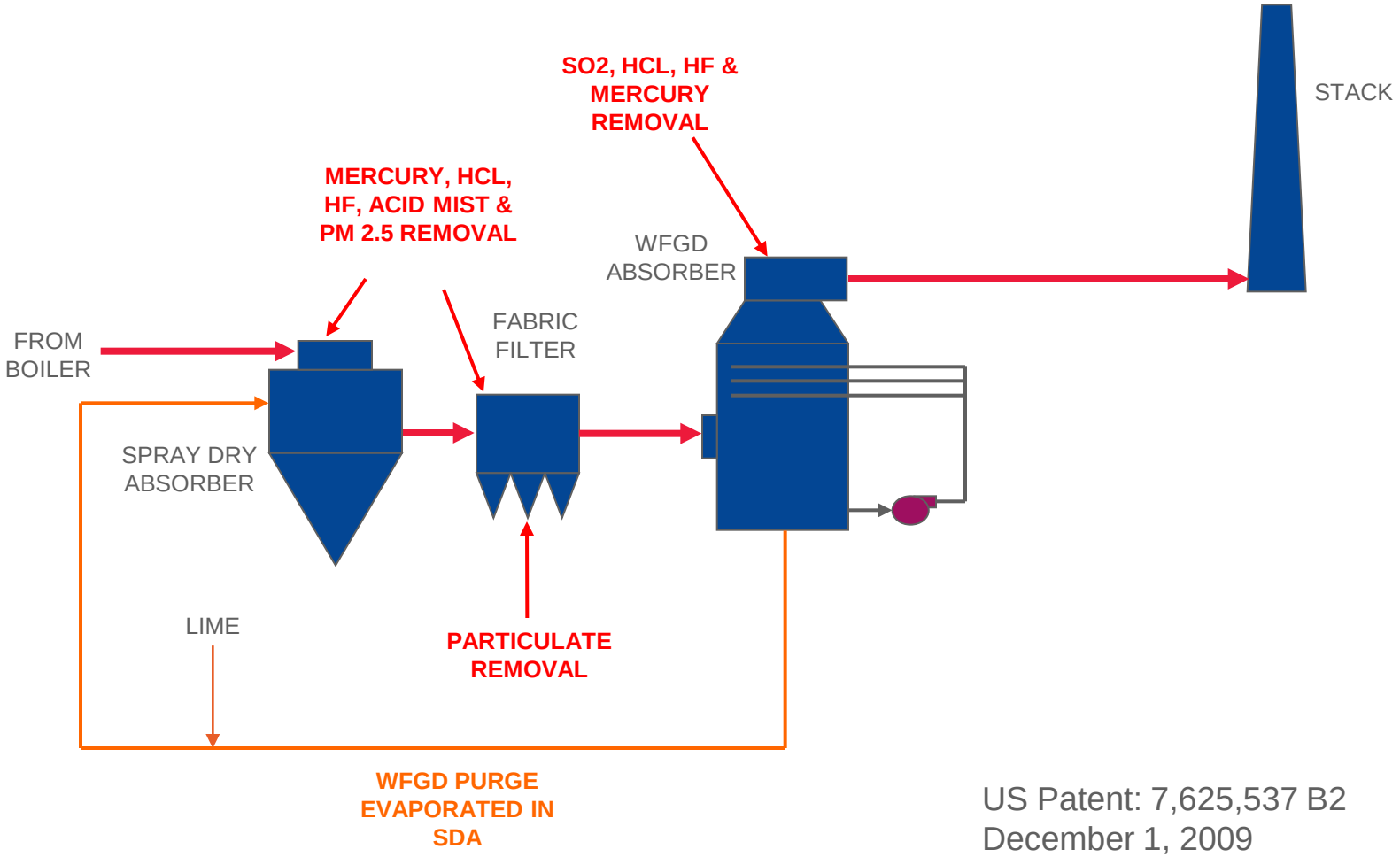
- Introduction
- Regulatory Drivers
- Technology Options
- **Direct Evaporation ZLD**
- Case Studies
- Summary

Direct Evaporation circa 1981



US Patent: 4,366,133
June 1, 1981

Cliffside 6 Integrated AQCS



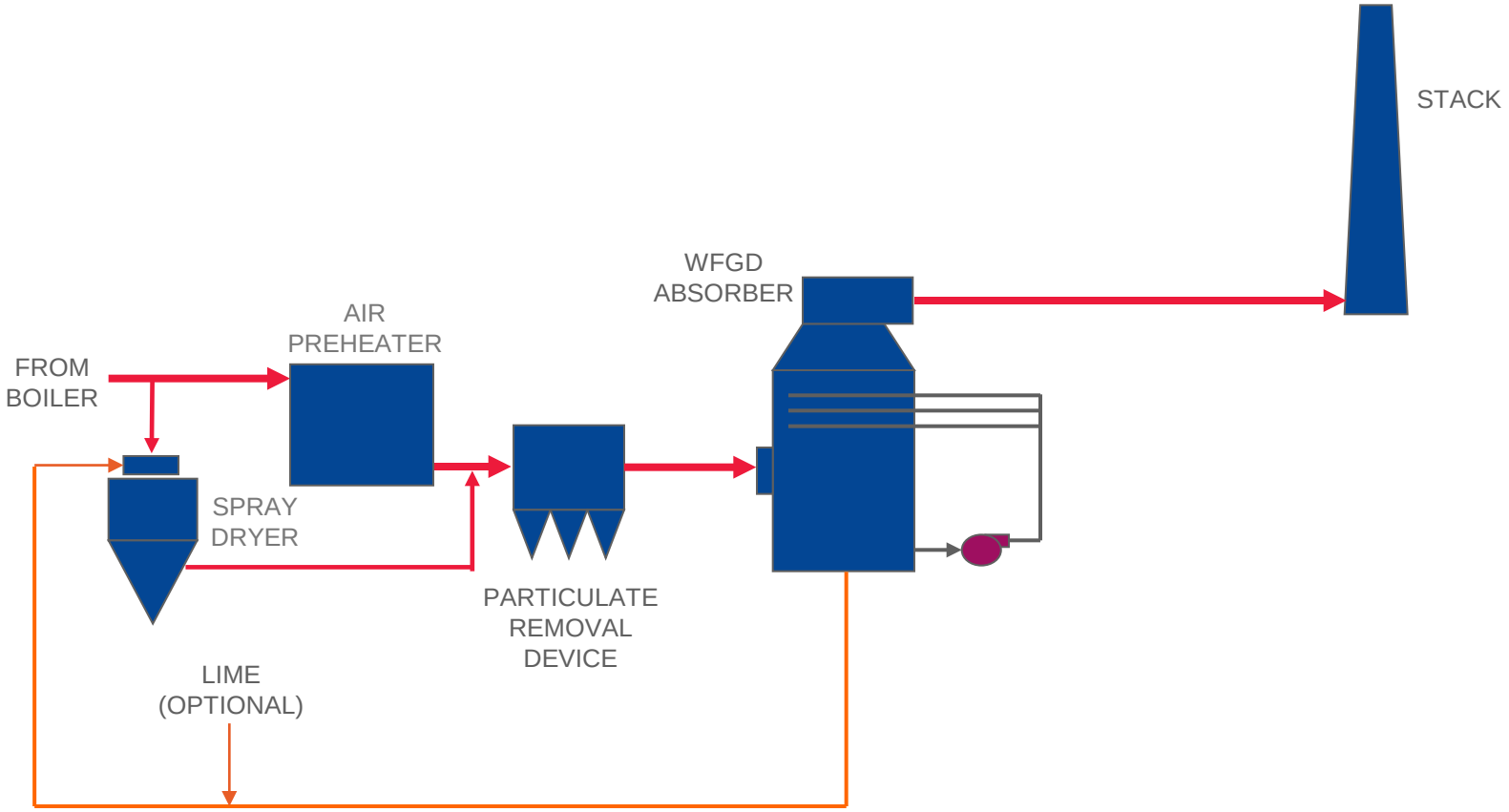
US Patent: 7,625,537 B2
December 1, 2009

Integrated AQCS Benefits

- Combines proven SDA/FF/WFGD technologies
- Excellent SO_3 control
- Low lime reagent consumption
- Eliminates waste water treatment system
- Possible to operate with lower chloride level in WFGD
- Fuel flexibility - up to 3000 ppm Cl fuel for Cliffside
- SDA/FF/WFGD – strong Hg emission control solution
- Reduces water consumption

ALSTOM

Slipstream SDE for WFGD Purge



US Patent Application
14/146,424
January 2014

Slipstream DFGD for WFGD Purge Evaporation

- 5 to 10% APH bypass for most applications
- Reintroduce SDE effluent at or above APH outlet temperature
- Hot gas reduces equipment size and cost
- Lime addition to purge stream for high S coals for:
  - Corrosion mitigation
  - Co-benefits for SO_3 and HCl control expected
  - Improves bag life
- Dissolved and suspended solids dried and collected by existing particulate control system

True Zero Liquid Discharge

ALSTOM

SDA vs. SDE

Spray Dryer Absorber

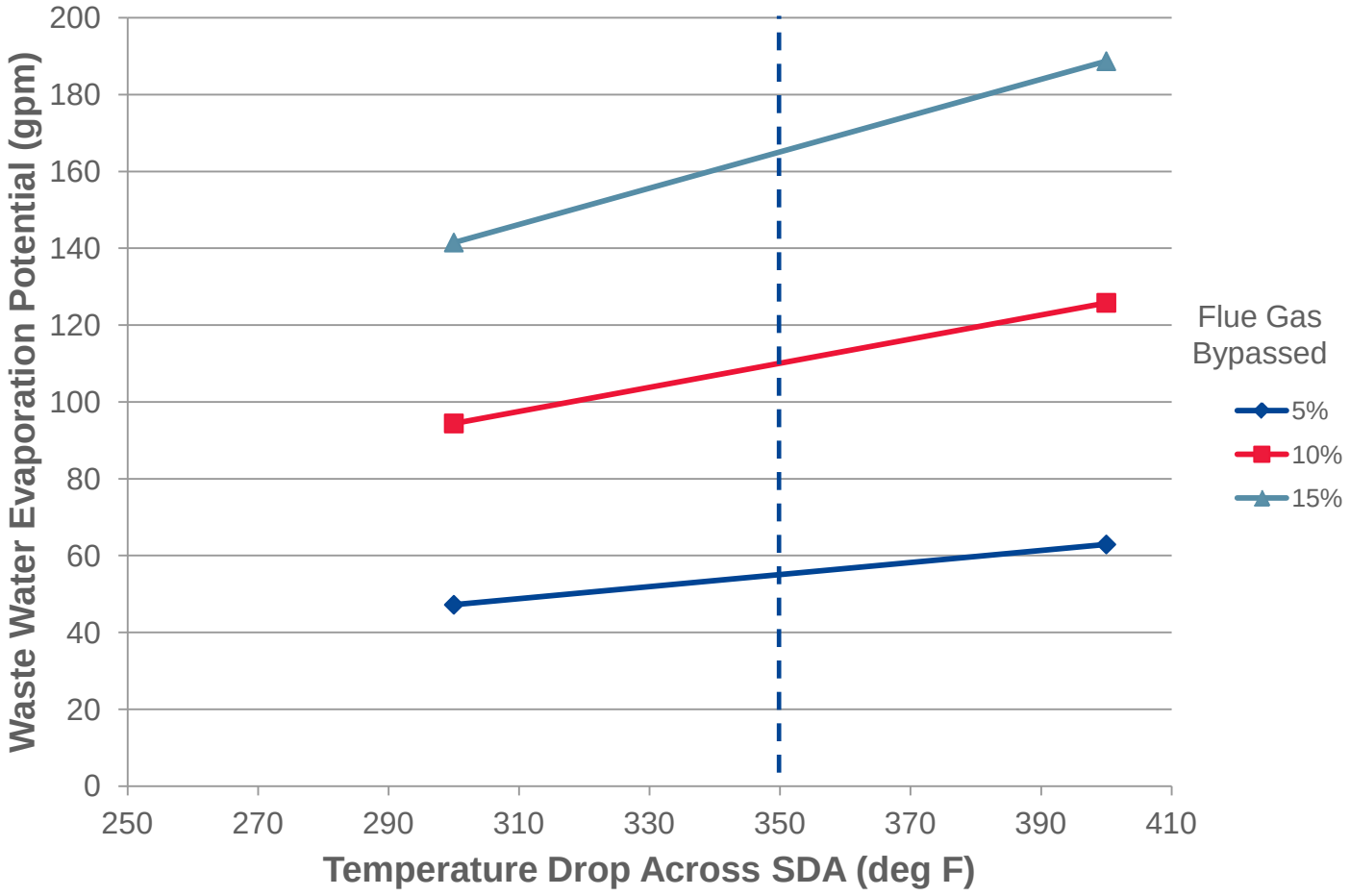
- Gas/liquid mass transfer plus drying
- 25-40% suspended solids in feed
- T_{in} = 300˚F
  T_{out} = 160˚F
  AST = 30˚F
- GRT = 12-14 sec

Spray Dryer Evaporator

- Evaporation
- 0.5-5% suspended solids in feed
- T_{in} = 700˚F
  T_{out} = 280 - 350˚F
  AST = > 160˚F
- GRT = 3-6 sec

ALSTOM

Waste Water Evaporation Potential
600 MW Plant



Slipstream SDA offers significant evaporation capacity

ALSTOM

Integrated Solutions

SPRAY DRYER EVAPORATOR

FROM BOILER

AIR PREHEATER

SPRAY DRYER EVAPORATOR

PARTICULATE COLLECTOR

WFGD SYSTEM

STACK

WFGD PURGE

OTHER WASTE STREAMS

VOLUME REDUCTION

BRINE CONCENTRATOR

REVERSE OSMOSIS

Alstom Spray Dryer Atomization Technology

Rotary Atomizer

Dual Fluid Nozzles

Rotary vs. Dual Fluid Nozzle Atomization

Rotary Atomizer

- Single rotary atomizer
- Larger diameter, shorter vessel
- Lower power consumption
- Higher pressure drop
- Good turndown

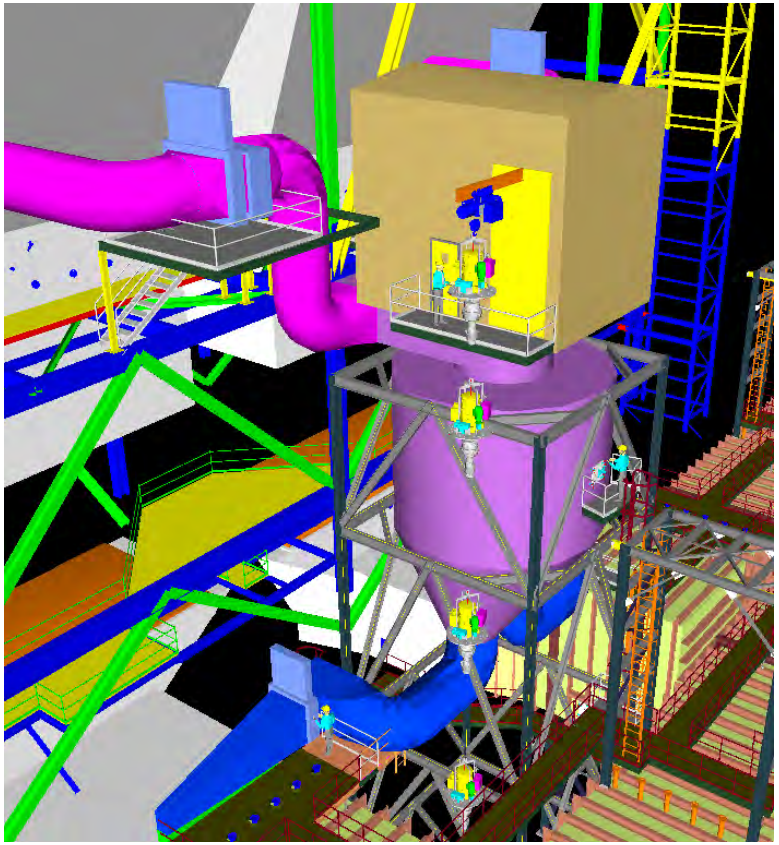
Dual Fluid Nozzles

- 4-8 dual fluid nozzle lances
- Smaller diameter, taller vessel
- Higher power consumption
- Lower pressure drop
- Good turndown

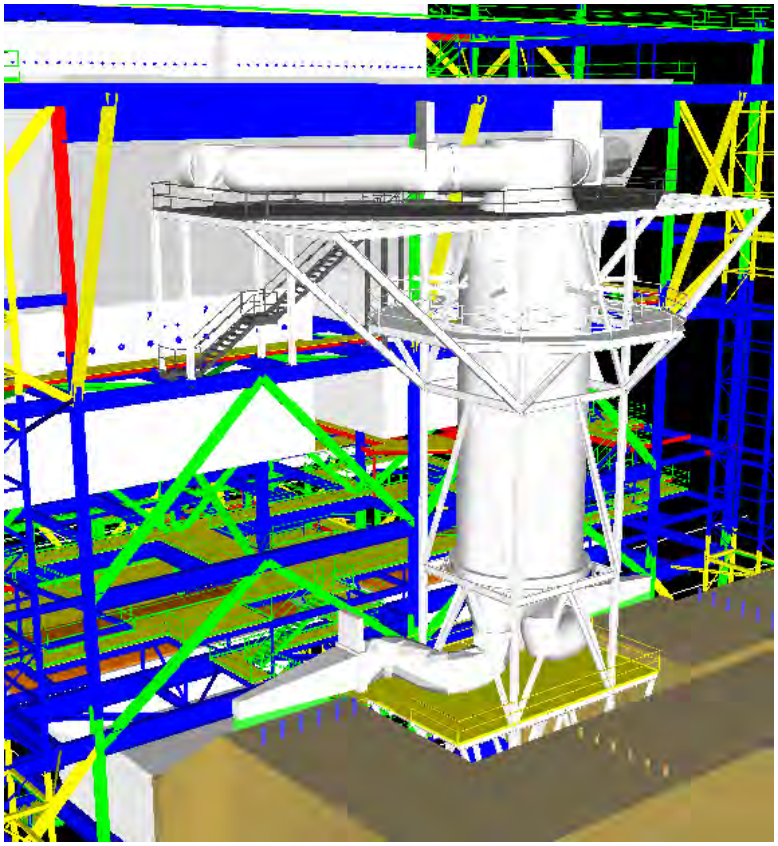
Two proven technology options

ALSTOM

SDE Alternatives



Rotary Atomizer



Dual-Fluid Nozzles

- Introduction
- Regulatory Drivers
- Technology Options
- Direct Evaporation ZLD
- **Case Studies**
- Summary

Duke Energy Cliffside 6 AQCS

Project Scope	Spray dryer, fabric filter, spray tower, lime/limestone preparation and feed systems, by-product dewatering system, ductwork, fans, erection and commissioning advisors
Location	Cliffside, NC
Capacity	825 MW
Start-Up	May 2012
Fuel	Eastern Bituminous
SO2 Removal	99% with 5 lbs/mmBtu fuel
No. Absorbers	Two spray dryers; one spray tower
By-product	Commercial gypsum
Gas Flow	2,800,000 ACFM
Reagent	Lime, limestone

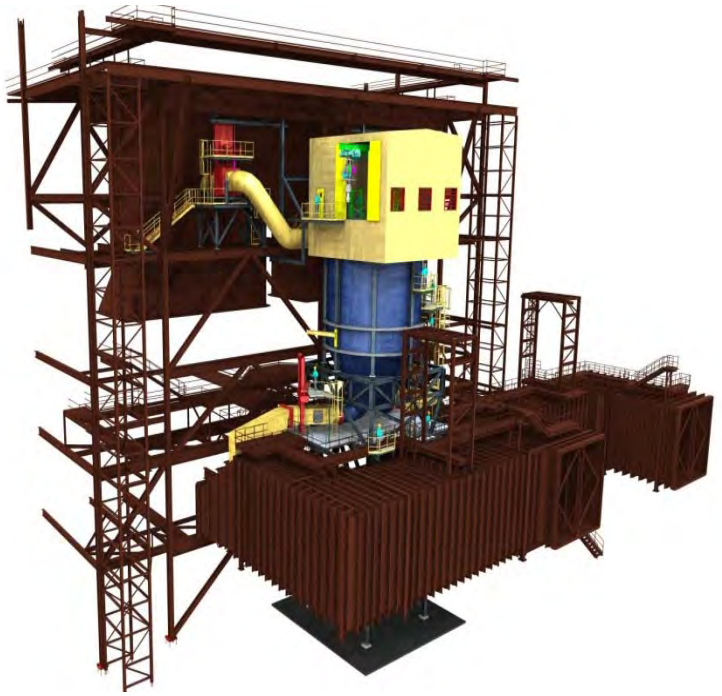
Duke Energy
Cliffside Unit 6
Cliffside, NC

Over 100,000,000 Gallons of Waste Water Evaporated to Date

ALSTOM

Large Mid-West Generation Station

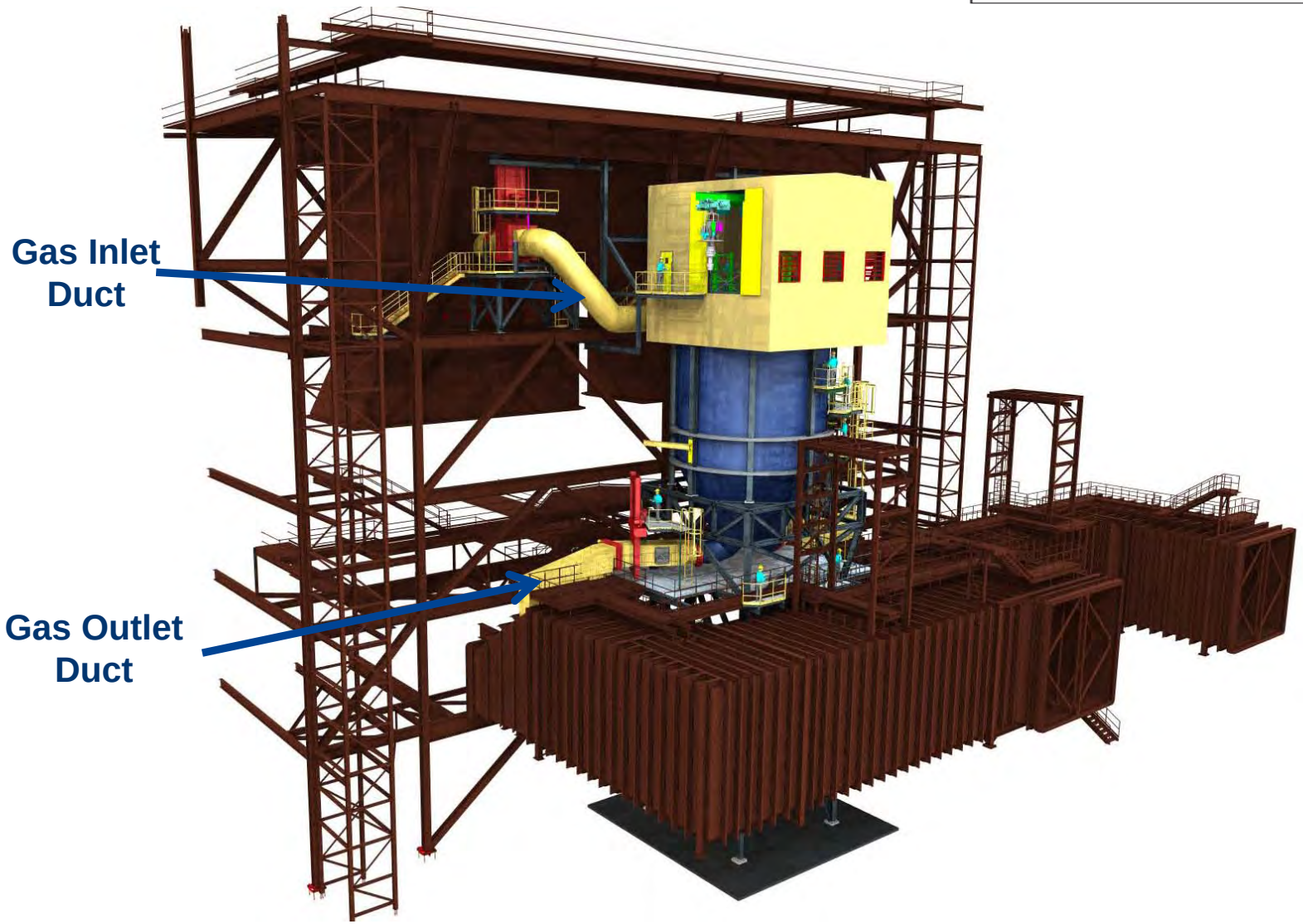
Project Scope	Spray dryer evaporator, rotary atomizers, lime softening system, ducts, dampers, support steel, access platforms, penthouse
Location	Mid West US
Start-Up	October 2016
Capacity	50 gpm WFGD waste water
Size	28 ft dia x 22 ft SS
No. Atomizers	1 operating + 1 spare
Materials	Carbon steel
WW Source	WFGD purge from 2 Units
WW Analysis	2-16% TSS, up to 140,000 ppm TDS
Gas Flow	150,500 acfm
Gas Inlet Temp	700 F, 630-730 F range



First Full-Scale SDE Installation in US

ALSTOM

SDE Arrangement

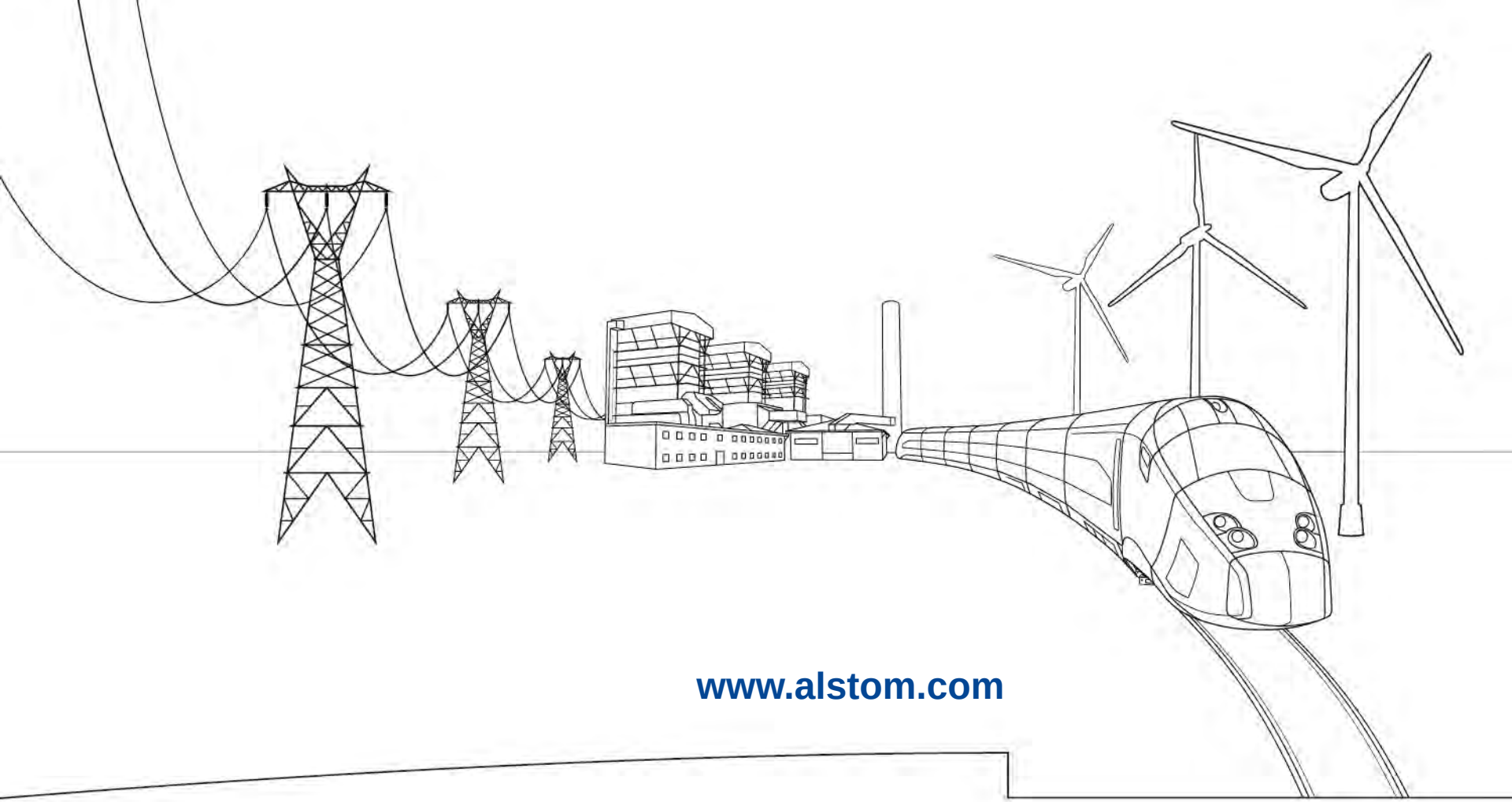


- Introduction
- Regulatory Drivers
- Technology Options
- Direct Evaporation ZLD
- Case Studies
- **Summary**

Summary

- USEPA is in the process of finalizing Effluent Liquid Guidelines for power plants
- Guidelines will impact current operational practices at most coal-fired power stations
- Advantages of direct evaporation include:
  - Zero liquid discharge
  - Simplicity
  - Proven technology

ALSTOM



www.alstom.com

ALSTOM

Shaping the future